Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/US05/007363

International filing date: 07 March 2005 (07.03.2005)

Document type: Certified copy of priority document

Document details: Country/Office: US
Number: 11/074,370
Filing date: 07 March 2005 (07.03.2005)

Date of receipt at the International Bureau: 03 January 2006 (03.01.2006)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

World Intellectual Property Organization (WIPO) - Geneva, Switzerland
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APPLICATION NUMBER: *11/074,370*
FILING DATE: *March 07, 2005*
RELATED PCT APPLICATION NUMBER: *PCT/US05/07363*

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS *US11/074,370*

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PTO/SB/05 (08-03)
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	006-529-000
First Inventor	G. Brandt Taylor et al.
Title	ELECTRONIC VALVE ACTUATOR
Express Mail Label No.	EL974045587US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

ACCOMPANYING APPLICATION PARTS

1.		Fee Transmittal Form (e.g., PTO/SB/17) (submit an original and a duplicate for fee processing)
2.	X	Applicant claims small entity status. See 37 CFR 1.27
3.	X	Specification [Total Pages 11] Both the claims and abstract must start on a new page *(For information on the preferred arrangement, see MPEP 608.01(a))*
4.	X	Drawing(s) (35 U.S.C. 113) [Total Pages 6]
5.		Oath or Declaration
a.		Newly executed (original or copy)
		A copy from a prior application (37 CFR 163(d)) (for continuation/divisional with Box 18 completed)
i.		Deletion of Inventor(s) Signed statement attached deleting inventor(s) name in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6.		Application Data Sheet. See 37 CFR 1.76
7.		CD-Rom or CD-R in duplicate, large table or Computer Program (Appendix)
		Landscape Table on CD
8.		Nucleotide and/or Amino Acid Sequence Submission *(if applicable, items a.-c. are required)*
a.		Computer Readable Form (CRF)
b.		Specification Sequence Listing on:
i.		CD-ROM or CD-R (2 copies); or
c.		Statements verifying identity of above copies

9.		Assignment Papers (cover sheet & document(s))
		Name of Assignee_____
10.		37 CFR 3.73(b) Statement (when there is an assignee)
		Power of Attorney
11.		English Translation Document (if applicable)
12.		Information Disclosure Statement (PTO/SB/08 or PTO-1449)
		Copies of citations attached
13.		Preliminary Amendment
14.	X	Return Receipt Postcard (MPEP 503)
		(Should be specifically itemized)
15.		Certified Copy of Priority Document(s) (if foreign priority is claimed)
16.		Nonpublication Request under 35 U.S.C. 122(b)(2)(B)(i). Applicant must attach form PTO/SB/35 or equivalent.
17.		Other:

18. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in the first sentence of the specification following the title, or in an Application Data Sheet under 37 CFR 1.76:

☐ Continuation ☐ Divisional ☐ Continuation-in-Part (CIP) of prior application No.:_____

Prior application information: Examiner_____ Art Unit_____

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Attorney Docket No.: 006-529-000

APPLICATION NO.	FILING DATE
To be assigned	Herewith

TITLE OF INVENTION

ELECTRONIC VALVE ACTUATOR

APPLICANT(S)

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EXPRESS MAIL CERTIFICATE

"EXPRESS MAIL" Label Number: EL974045587US

DATE OF DEPOSIT: March 7, 2005

I hereby certify that the following attached paper(s) or fee(s) Utility Patent Application Transmittal; Patent Application - 8 pgs. of specification, 2 pgs. of claims (1-6) and 1 pg. Abstract; 6 Sheets of drawings (FIGS. 1-3c); Return Postcardis/are being mailed with the UNITED STATES POSTAL SERVICE "EXPRESS MAIL POST OFFICE TO ADDRESSEE" service under 37 CFR 1.10 on the date indicated above and is/are addressed to the Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Gerry A. Blodgett

ELECTRONIC VALVE ACTUATOR

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit under 35 U.S.C. §119(e) of:

U.S. Provisional Application No. 60/551,199 filed March 8, 2004,

U.S. Provisional Application No. 60/566,112 filed April 28, 2004,

U.S. Provisional Application No. 60/574,414 filed May 24, 2004,

U.S. Provisional Application No. 60/578,548 filed June 10, 2004,

U.S. Provisional Application No. 60/605,943 filed August 31, 2004, and

U.S. Provisional Application No. 641,225 filed January 4, 2005, and

this application claims the benefit under 35 U.S.C. §120 of:

an Patent Cooperation Treaty application filed on the same day (3/7/2005) as this application, entitled "Induction Sensor", by the same inventors as this application,

all of which applications are hereby incorporated by reference.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

This invention has been created without the sponsorship or funding of any federally sponsored research or development program.

BACKGROUND OF THE INVENTION

Solenoid systems for electromagnetic actuation of engine valves are well known in the art. These systems are required to move a valve between open and closed positions that are far apart in a short time. Previous designs have relied on mechanical springs to store part of the energy in the system in order to lessen the power requirement of the solenoid and to improve control of valve's acceleration and deceleration. It would be desirable to develop a system that would make it practical to eliminate the mechanical spring used in an electromagnetic valve actuator.

Since the magnetic attractive force between two parallel surfaces decreases as the distance increases by the square of the distance and the force is proportional to the area of the

surfaces, the magnetic interaction between conventional flat to parallel surfaces employed and prior art designs impose serious limitations. It would be desirable to develop geometric techniques that would increase the effective power of the solenoid system and improve energy efficiency.

Thus, existing actuators employ mechanical springs that complicate and increase the cost of the actuators and contribute to maintenance difficulties. Furthermore, existing actuators employ the solenoid systems that are not efficient producers of force and therefore also complicate increase the cost of the actuators and contribute to maintenance difficulties.

These and other difficulties experienced with the prior art devices have been obviated in a novel manner by the present invention.

It is, therefore, an outstanding object of the present invention to provide an actuator which increases electromagnetic effectiveness over the range of movement.

Another object of this invention is to provide an actuator this simple in construction in design.

A further object of the present invention is to provide an actuator which is compacted in design and therefore allows a high degree of flexibility in integrating the actuator into mechanical systems.

It is another object of the invention is to provide an actuator that allows precise and reproducible motion.

It is a further object of the invention to provide an actuator that is capable of being manufactured of high quality and at a low cost, and which is capable of providing a long and useful life with a minimum of maintenance.

With these and other objects in view, as will be apparent to those skilled in the art, the invention resides in the combination of parts set forth in the specification and covered by the

claims appended hereto, it being understood that changes in the precise embodiment of the invention herein disclosed may be made within the scope of what is claimed without departing from the spirit of the invention.

BRIEF SUMMARY OF THE INVENTION

This invention is a valve actuator for controlling movement of poppet valves (inlet valve and exhaust valve) and internal combustion engines. The actuator includes an armature is mounted on the stem of the valve. The armature has a convex surface on its front and a convex on the rear. In one embodiment the surfaces would be tapered with a wedge shape. The taper would be approximately eighteen degrees from the axis of the valve stem. The actuator also includes electromagnets with concave surfaces that conformed to the convex surfaces of the armature. The electromagnets are arranged so that they can be selectively activated to cause movement of the valve. The complementary geometry of the armatures and magnets enhance the effectiveness of the magnetic field cost by the electromagnets on the armature.

BRIEF DESCRIPTION OF THE DRAWINGS

The character of the invention, however, may best be understood by reference to one of its structural forms, as illustrated by the accompanying drawings, in which:

Fig 1a shows magnetic circuits for a prior art valve actuator,

Fig 1b shows magnetic circuits for a valve actuator of the present invention,

FIG. 2 includes FIGs. 2a-k,

Fig 2a shows a front elevation sectional view of valve actuator with tapered armature, said actuator embodying the principles of the present invention, in the valve closed position,

Fig 2b shows a front elevation sectional view of valve actuator with tapered armature, said actuator embodying the principles of the present invention, in the valve open position,

Fig 2c shows a front elevation view of an armature and valve stem used in a valve actuator embodying the principles of the present invention,

Fig 2d shows a right side elevation view of an armature and valve stem used in a valve actuator embodying the principles of the present invention,

Fig 2e shows a front elevation sectional view of an armature and valve stem used in a valve actuator embodying the principles of the present invention, the section as viewed along line AA of Fig. 2d,

Fig 2f is a plan view of a coil assembly and actuator body embodying the principles of the present invention,

Fig 2g is a front elevation view of a coil assembly and actuator body embodying the principles of the present invention,

Fig 2h is a right side elevation view of a coil assembly and actuator body embodying the principles of the present invention,

Fig 2i is a front elevation view of the left coil in the coil assembly and actuator body shown in Fig. 2g,

Fig 2j is a left side elevation view of the coil assembly and actuator body shown in Fig. 2g,

Fig 2k is a sectional front elevation view of the coil assembly and actuator body shown in Fig. 2g, as seem along the line CC of Fig. 2h,

Fig 2l is a sectional front elevation view of the coil structure shown in Fig. 2i, as seem along the line BB of Fig. 2j,

Fig 2m is a sectional front elevation view of the coil structure shown in Fig. 2i, as seem along the line DD of Fig. 2j,

Fig. 3 includes Figs. 3a-c,

Fig 3a shows a front elevation view of an alternate valve and armature arrangement for use when the valve itself is nonmagnetic,

Fig 3b shows a right side elevation view of the arrangement shown in Fig. 3a, and

Fig 3c shows a sectional front elevation view of the arrangement shown in Fig. 3a, taken along line AA of Fig. 3b.

DETAILED DESCRIPTION OF THE INVENTION

Fig 1a shows a magnetic circuit for a prior art actuator used for operating engine valves. Coil 1a is wound on magnetic member 2a. Magnetic member 2a is attached to two magnetic members 3a. The coil 1a and the members 2a and 3a form the coil assembly. Magnetic member 4a, which is the movable part, is attracted to the coil assembly by magnetic attraction. Flux lines 9a depict the path of the magnetic flux. The flux lines traverse air gap 7a and air gap 10a in their circuit. Surfaces 5a and surface 8a define the area of air gap that must be traversed. In practice, surface area 10a is equal to the sum of the two surface areas 5a. The distance that separates the magnetically attractive surfaces is typically about 8 mm. The part of the flux path that is in the magnetic members is typically about 48 mm. For a given magneto motive force A (mmf), the solenoid system of Fig 1a produces 1 unit of attractive force between member 4a and the coil assembly 12a.

Fig 1b shows a magnetic circuit of the present invention. The two drawings Fig 1a and Fig 1b are drawn to scale so that they both depict the same lateral distance of separation of the movable part 4a and 4 from the coil assembly 12a and 12. That distance is 8 mm. As in Fig 1a, coil 1 is wound on magnetic member 2. Magnetic member 2 is attached to two magnetic

members 3. Surfaces 9 on part 4 are in close relation to surfaces 8 on parts 3. The distance that separates each surface 9 from each surface 8 in Fig 1b is 0.4 mm. Area 9 of Fig 1b is the same area as area 8 of Fig 1a. Note that the force acting between part 4 and parts 3 is normal to their surfaces and does not contribute to attraction between part 4 and the coil assembly 12. By effecting these changes to the magnetic circuit the attractive force between hypothetical member 4 and a hypothetical coil assembly is increased to 1.7 units from the same magneto motive force A.

In Fig 1b, part 4 has tapered surface 6 through which the magnetic flux passes on its way to matching taper 5 on part 3. The taper angle (a) here is 18 degrees. The length of the flux path in air gap 7 is decreased because of the taper to 2.5 mm and also the area of the air gap is increased from 100 mm^2 to 300 mm^2. Now the flux path in the magnetic material has been increased to 72 mm. The force of attractive force Fa between the surfaces 5 and 6 is normal to them and hence the force in the direction of travel Ft is:

$$Ft = Fa \sin a$$

The result of this is that the solenoid system of Fig 1b produces 11 units of force from mmf A.

Fig 2 shows a valve actuator with tapered armature designed according to the technique used for part 4 of Fig 1b. Armature assembly 21 is comprised of armature 1 rigidly attached to shaft 4. Shaft 4 has tapered end 6 which is the actuator for valve position sensor coil 13. Armature 1 has tapered surface 2 and magnetic flux path 3. The tapered surface 2 forms an outside taper on the armature 1. The armature 1 can be made of laminated steel. Shaft 4 is made of non-magnetic material as 300 series stainless steel or titanium. Shaft 4 has coupling 5 for attachment of a valve 50. Two rectangular guides 23 are lodged in rectangular holes in the armature 1. The actuator body 20 is comprised of two coil assemblies 7 held in fixed relation by two support members 12. The actuator body contains sensor housing 14 that houses sensor coil 13. Support member 12 is made of magnetically permeable material and provides a pathway for magnetic flux to the flux paths 3 on the armature 1. Members 12 may be made of laminated steel. Each coil assembly 7 is comprised of coil 8 wound on magnetic

part 9 and bearing 11. The magnetic part 9 has internal taper 10 that matches the taper 2 of armature 1. Part 9 may be made of laminated steel. Actuator body 20 has 2 bearing blocks 24 attached to support members 12. Grooves 23@ on the inside of bearing blocks 24 receive guides 22 and absorb force normal to the direction of valve motion. The bearing blocks 24@ with guides hold the armature in correct radial relation to the coil assemblies. Valve 15 is attached to armature assembly 21 by coupling 5.

In one embodiment of this invention, the motion of the valve @@ from its open position to its closed position, is controlled through a the magnetic action of the coils by an electronic valve position controller @@. In one embodiment of this invention, the controller receives a signal from the valve position sensor @@. The signal is generated by the physical relationship between the tapered end 6 of the valve 15 and the valve position sensor coil 13. The signal is an accurate representation of the relative position of the valve in its range of movement. This signal allows the controller to recalibrate the position of the valve at its closed position during every valve opening cycle, and thereby more accurately control the movement of the valve. In this way, compensation for thermal expansion is determined and applied.

In one embodiment of the invention, the coupling 5 may be a rigid connection between the valve 15 and the armature shaft 4. This rigid connection is possible because the accuracy of the valve position sensor @@ allows a valve position controller @@ to recalibrate the position of the valve at its closed position during every valve opening cycle. In this way, compensation for thermal expansion is determined and applied, so the coupling 5 need not be expandable.

In some applications, it is possible to have the valve 15 extend through the armature and have no coupling 5 outside of the valve actuator. An example of this is when the valve material is titanium. Fig 3 shows a valve and armature assembly where the stem of the valve 15 extends through armature 1. In embodiment of this invention in which the valve position sensor relies on the magnetic properties of the tapered end 6 of the valve stem@@, in the case of a non-magnetic valve material such as titanium, a magnetic retainer 4@@ is attached to the

valve by coupling 5@@. The magnetic retainer 4@@ has tapered end 6@@ for valve position sensor operation and is sized to fit in the sleeve bearing associated thereto.

It is obvious that minor changes may be made in the form and construction of the invention without departing from the material spirit thereof. It is not, however, desired to confine the invention to the exact form herein shown and described, but it is desired to include all such as properly come within the scope claimed.

The invention having been thus described, what is claimed as new and desire to secure by Letters Patent is:

CLAIMS

1. A valve actuator with tapered armature as shown in Fig 2.

2. A valve actuator with guides that absorb force normal to the valve motion.

3. A valve actuator with flux paths perpendicular to the direction of valve motion.

4. A valve actuator with integral valve stem and armature shaft.

5. An engine valve system for use in an engine, the system adapted for moving an engine valve between an open position and a closed position, comprising:

a) an engine valve having a stem with an axis and a front end and a back end, the valve having a movement axis between the open position and closed position along the stem axis,

b) an armature mounted on the stem of the valve, the armature having a front nonplanar surface directed to the front end of the valve stem up, and back nonplanar surface directed to the back end of the valve stem,

c) a stator assembly mounted on the engine, the stator assembly being adapted to enclose the armature with the armature movable within the stator assembly, the stator assembly including a first magnetic field producing device including a first nonplanar surface of complementary shape to the front nonplanar surface of the armature, said first magnetic field producing device being adapted to selectively magnetically attracted the front nonplanar surface of the armature to the first nonplanar surface of the first magnetic field producing device, and the stator assembly also including a second magnetic field producing device including a second nonplanar surface of complementary shape to the back nonplanar surface of the armature, said second magnetic field producing device

being adapted to selectively magnetically attract the back nonplanar surface of the armature to the second nonplanar surface of the second magnetic field producing device.

6. An actuator for use in an engine, the system adapted for moving an engine valve between an open position and a closed position, said engine valve having a stem with an axis and a front end and a back end, the valve having a movement axis between the open position and closed position along the stem axis, comprising:

a) an armature mounted on the stem of the valve, the armature having a front nonplanar surface directed to the front end of the valve stem up, and back nonplanar surface directed to the back end of the valve stem, and

b) a stator assembly mounted on the engine, the stator assembly being adapted to enclose the armature with the armature movable within the stator assembly, the stator assembly including a first magnetic field producing device including a first nonplanar surface of complementary shape to the front nonplanar surface of the armature, said first magnetic field producing device being adapted to selectively magnetically attracted the front nonplanar surface of the armature to the first nonplanar surface of the first magnetic field producing device, and the stator assembly also including a second magnetic field producing device including a second nonplanar surface of complementary shape to the back nonplanar surface of the armature, said second magnetic field producing device being adapted to selectively magnetically attract the back nonplanar surface of the armature to the second nonplanar surface of the second magnetic field producing device.

ABSTRACT OF THE DISCLOSURE

Electromagnetic actuators are described for operating poppet valves in internal combustion engines.

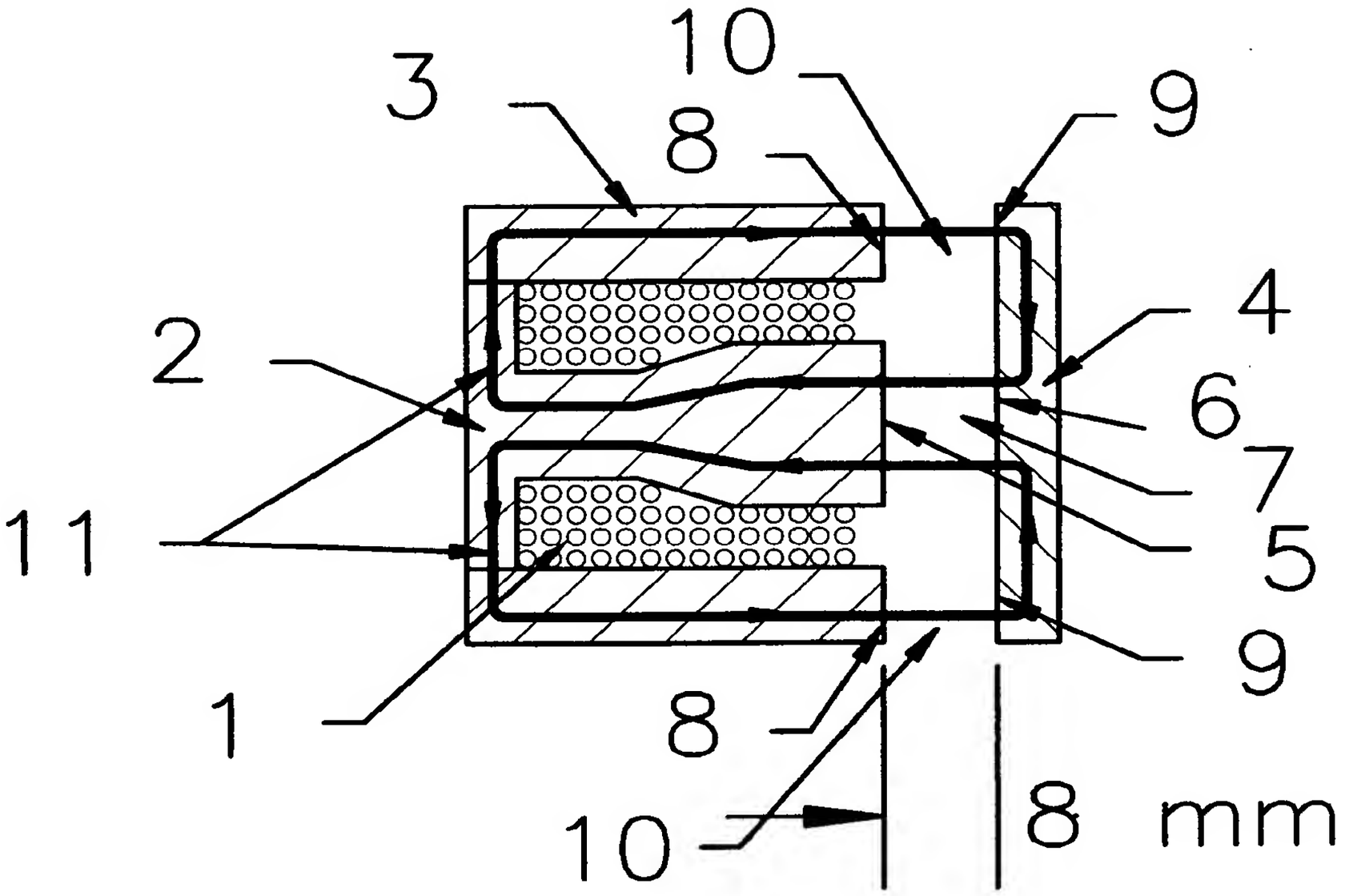


Fig 1a Prior Art

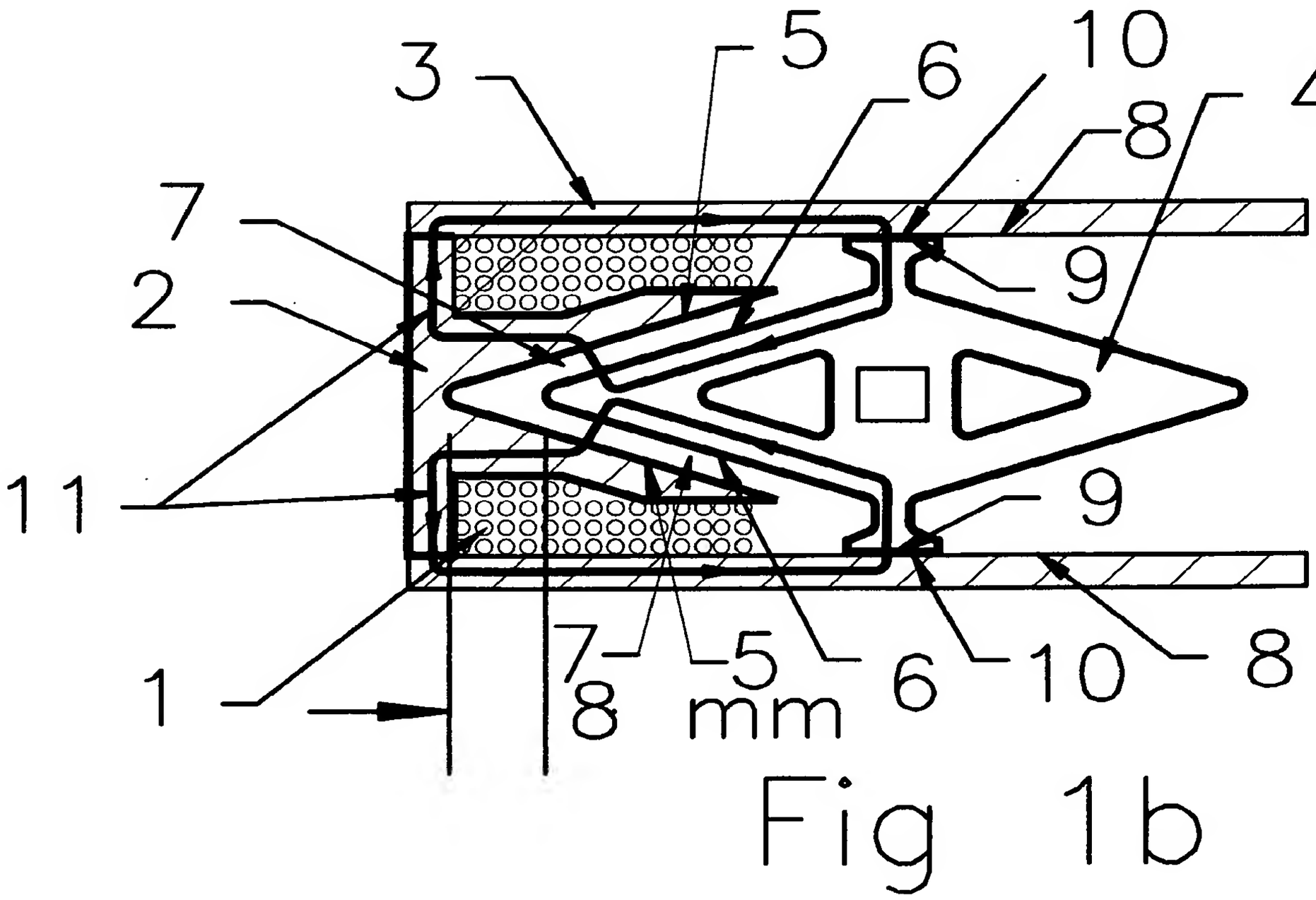
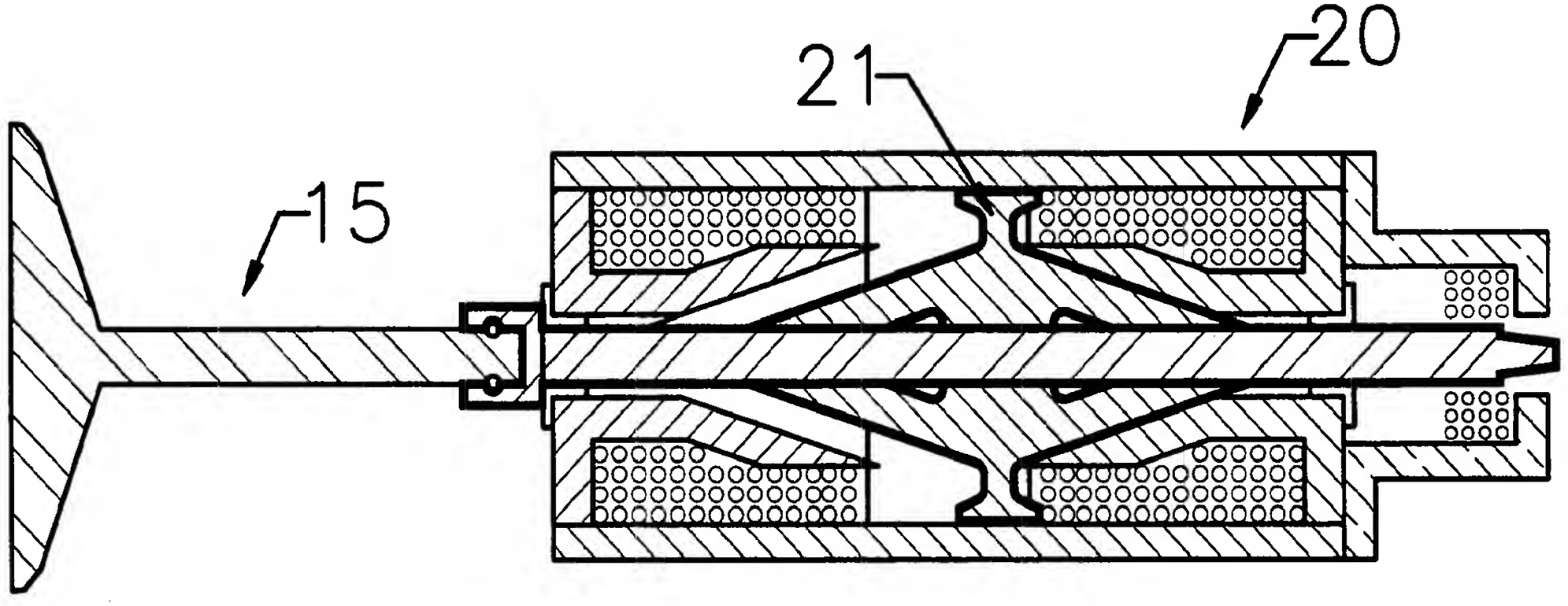


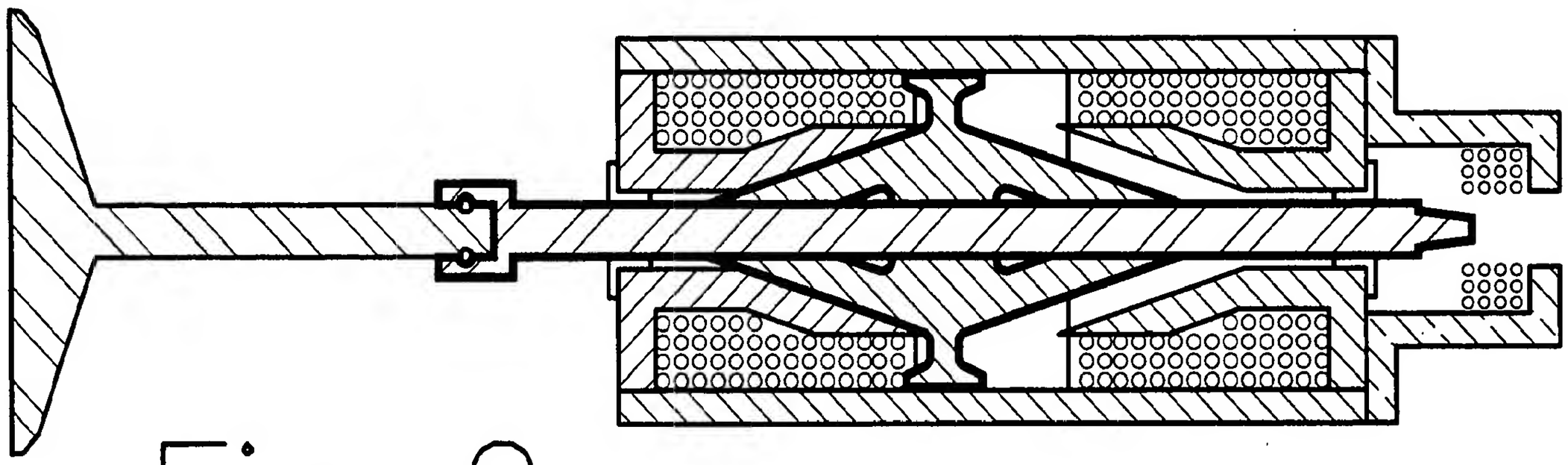
Fig 1b

Fig 2a



valve closed

Fig 2b



valve open

Fig 2

Fig 2c

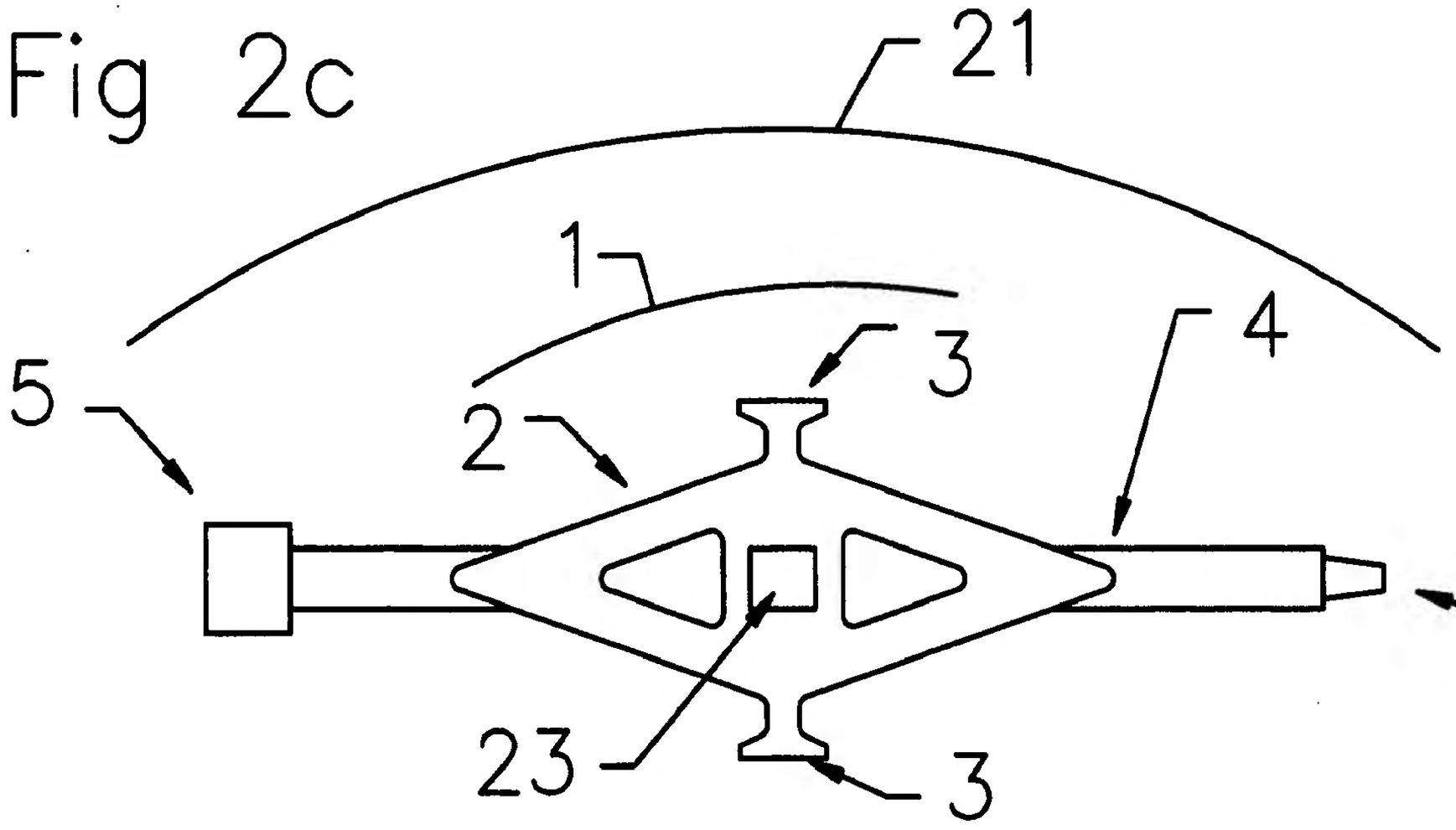


Fig 2d

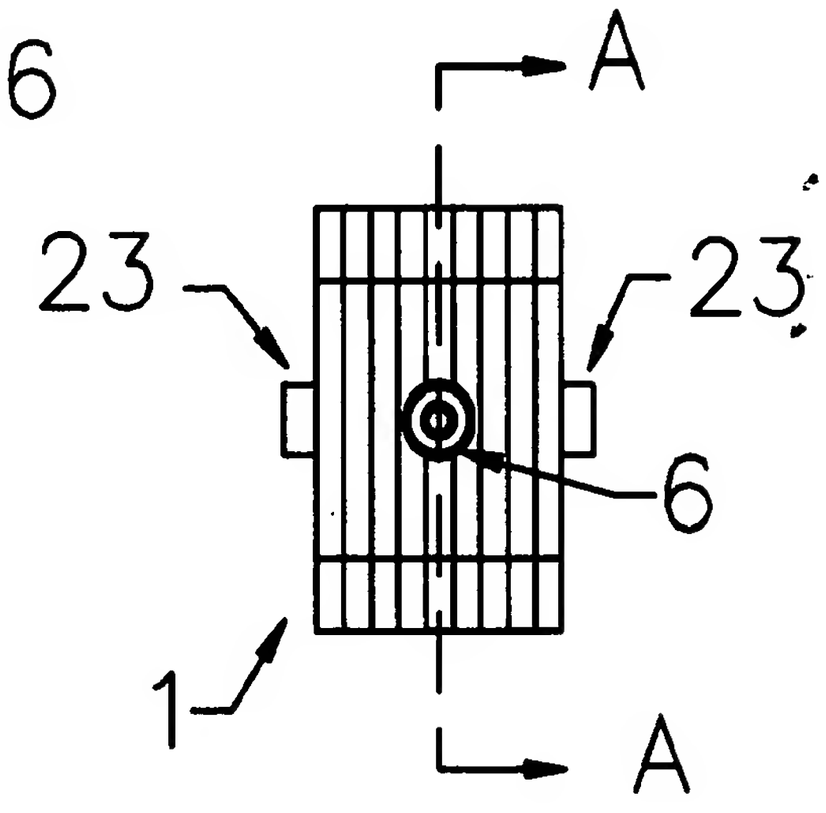
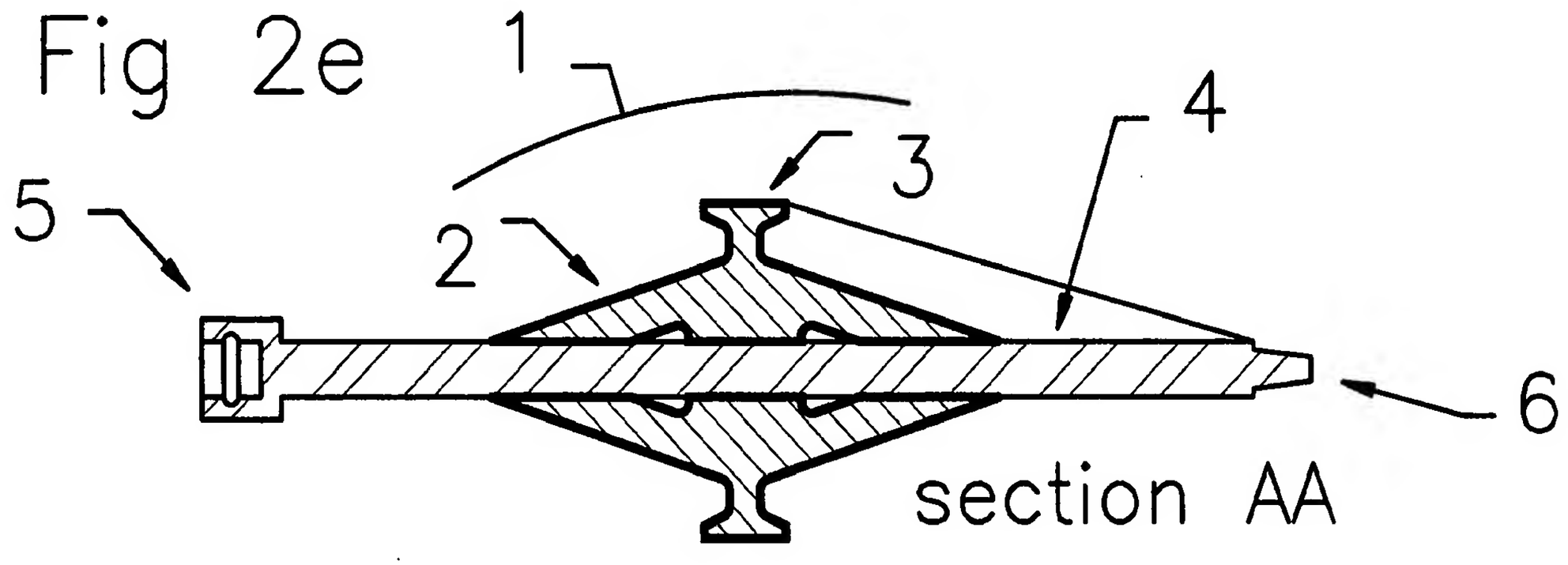


Fig 2

Fig 2e



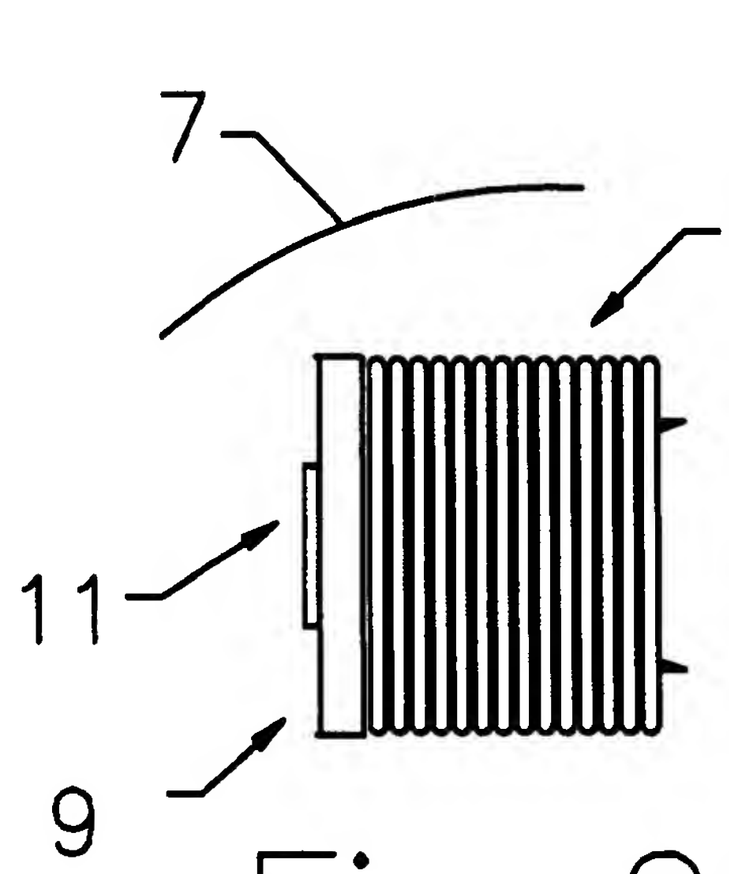


Fig 2j

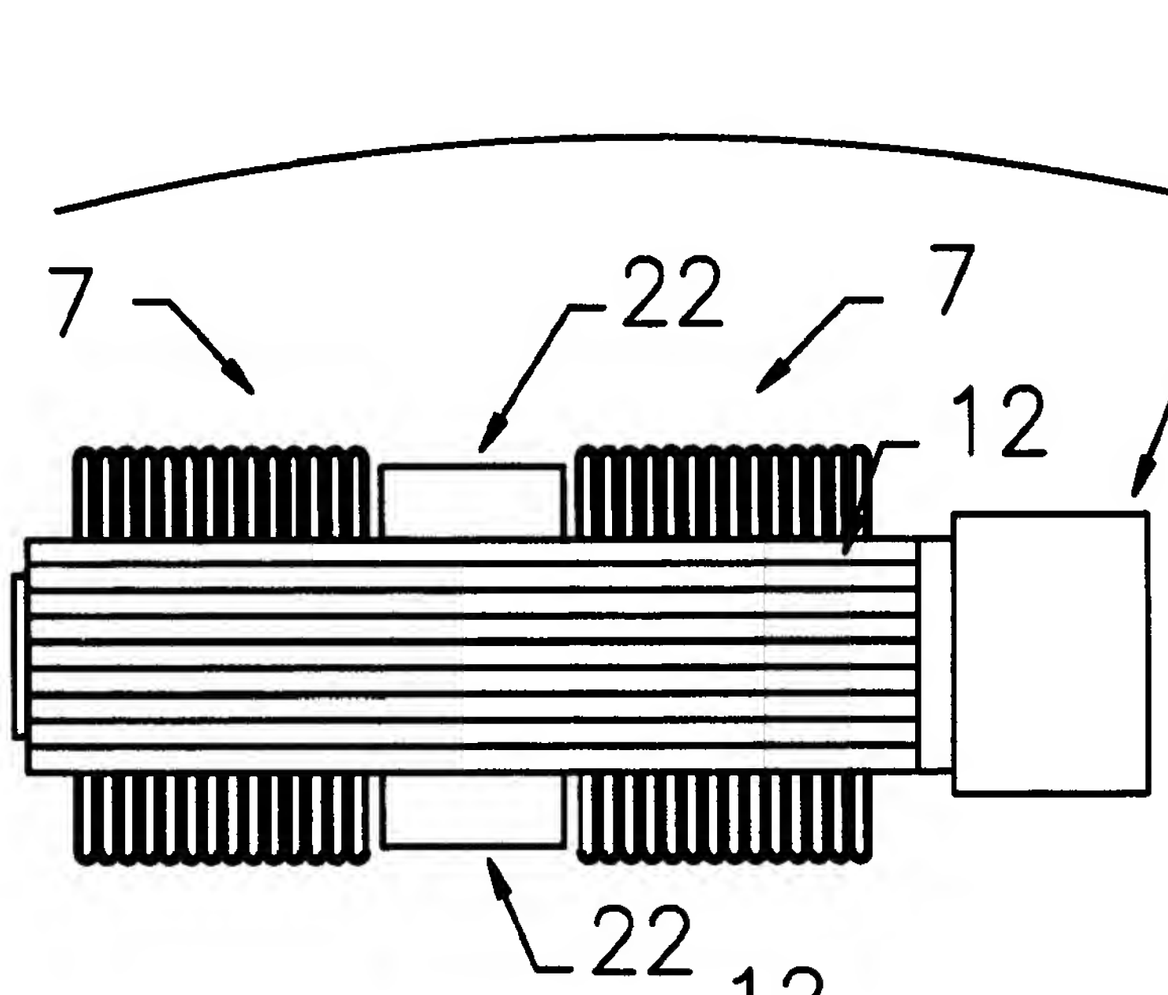


Fig 2f

Fig 2h

Fig 2g

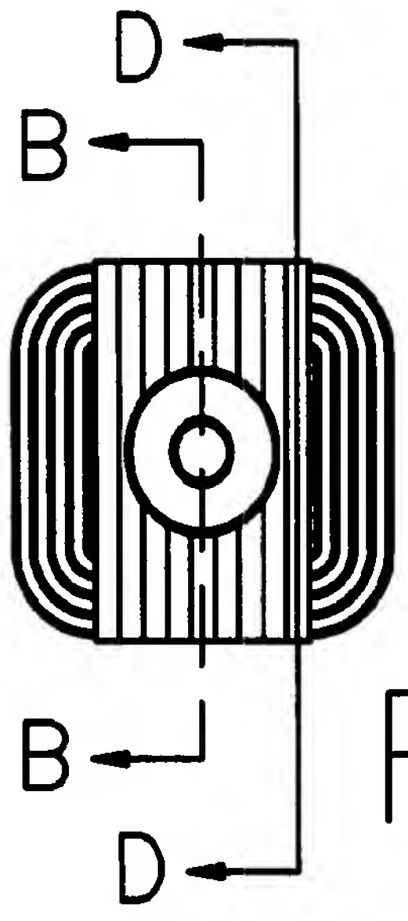


Fig 2i

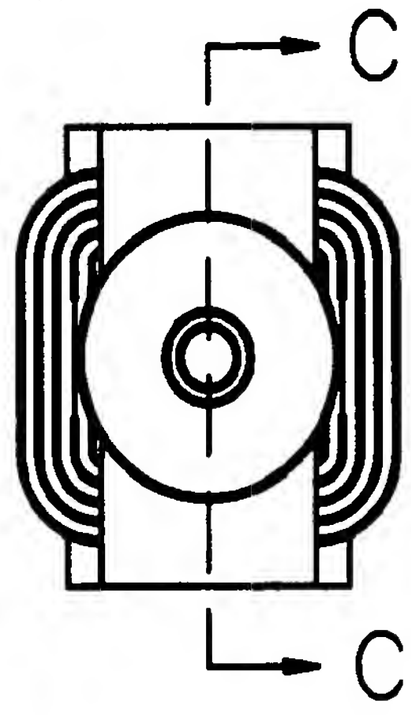
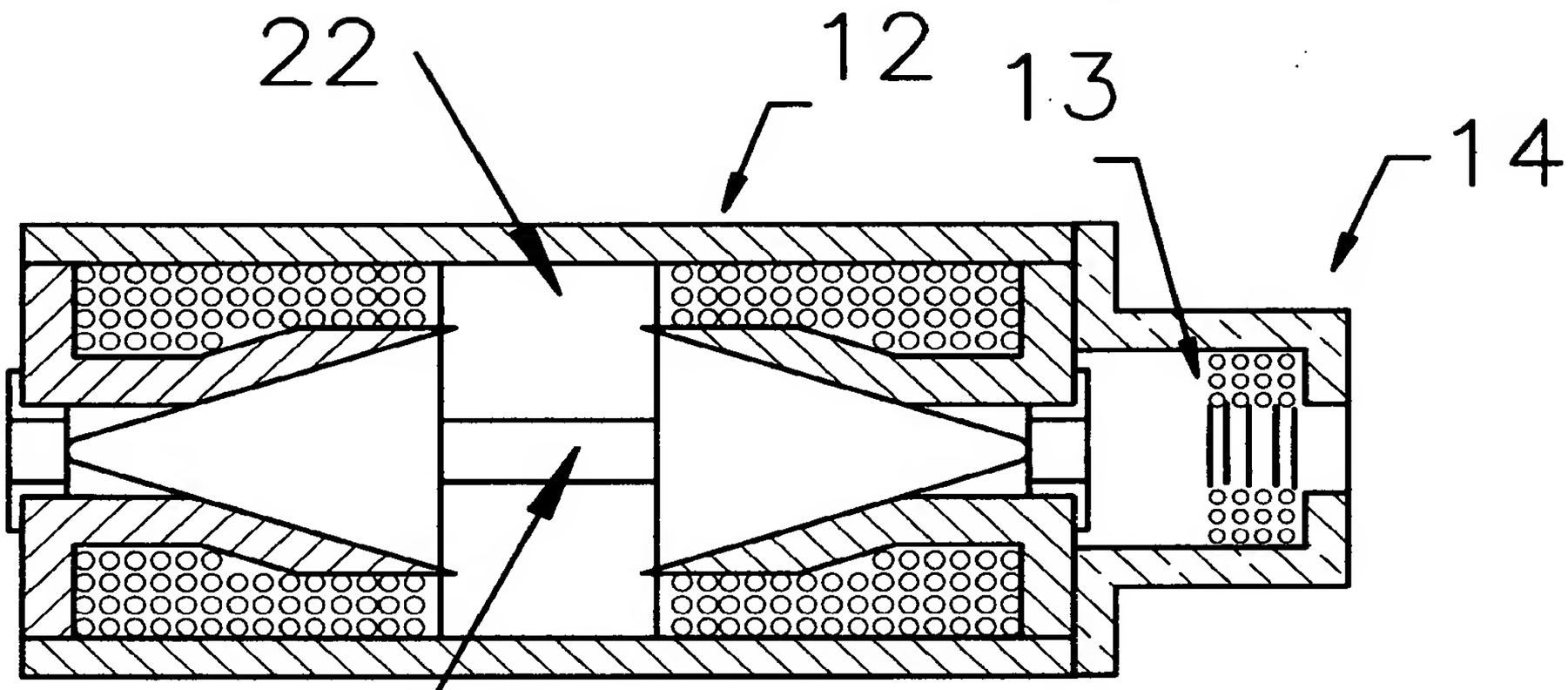
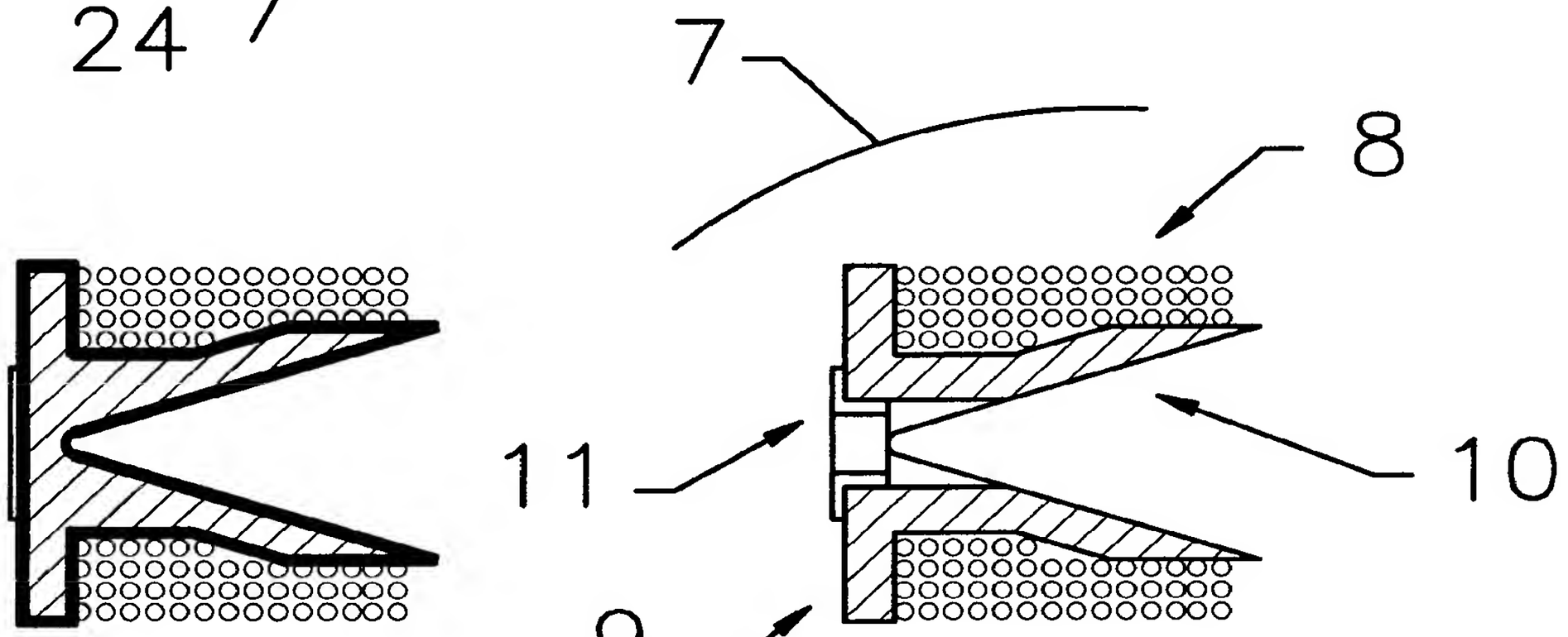


Fig 2

Fig 2k



section CC



section DD

section BB

Fig 2m

Fig 2l

Fig 2

Fig 3a

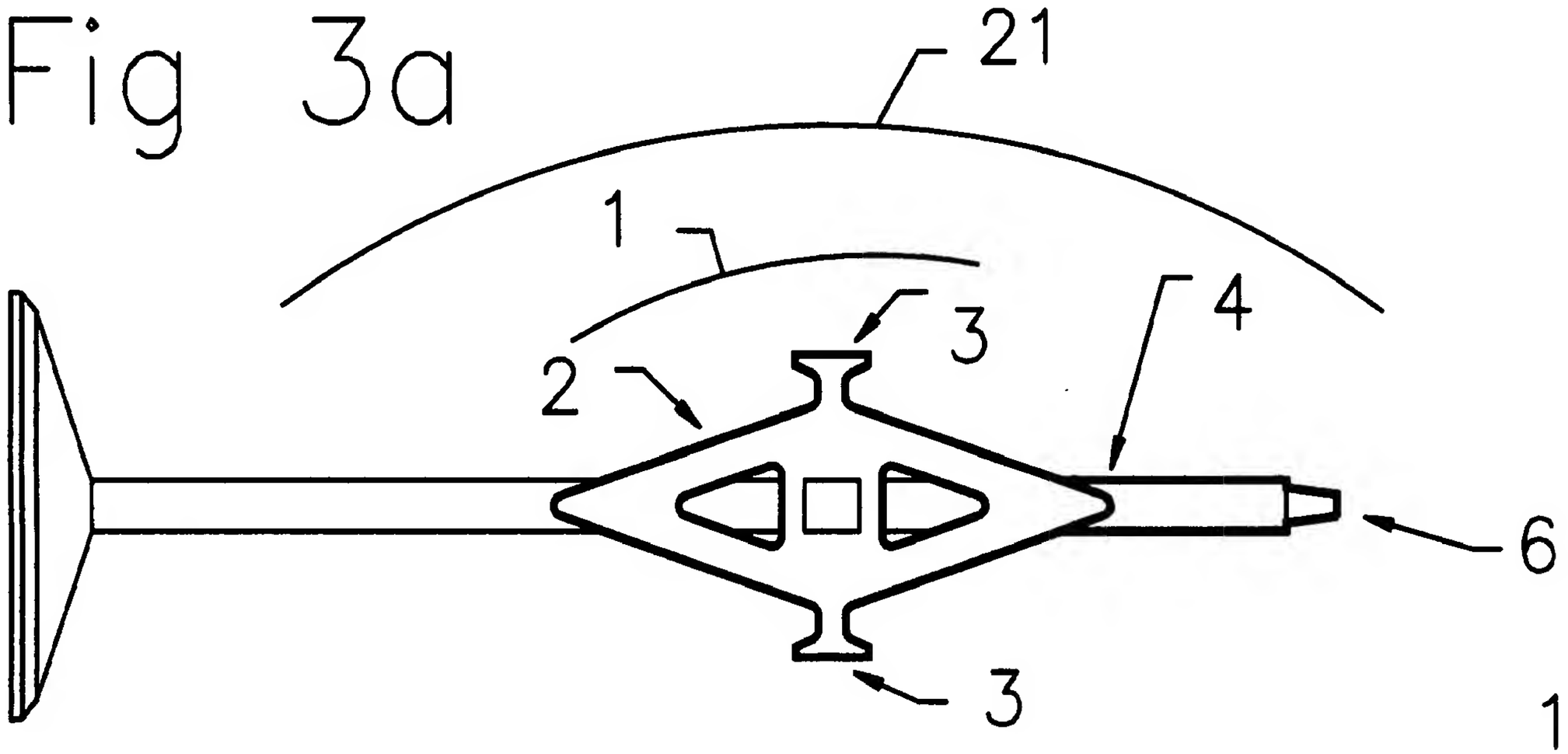
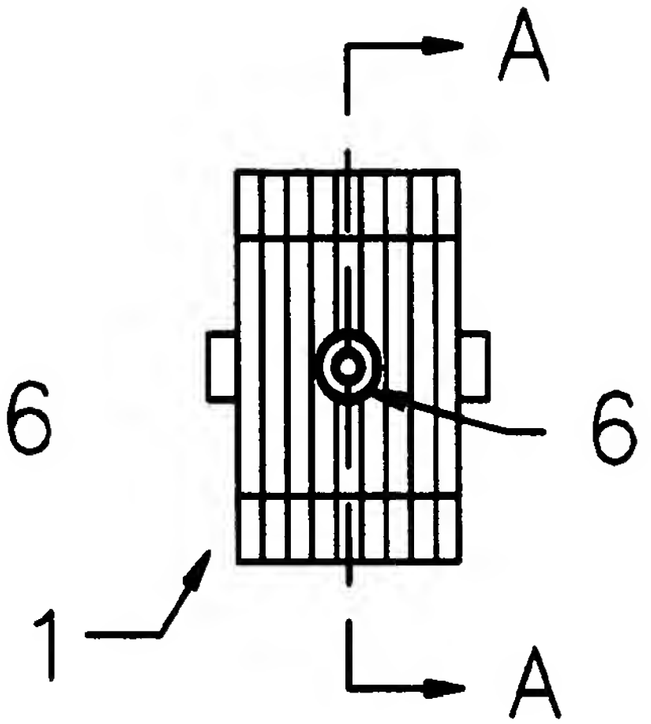


Fig 3b



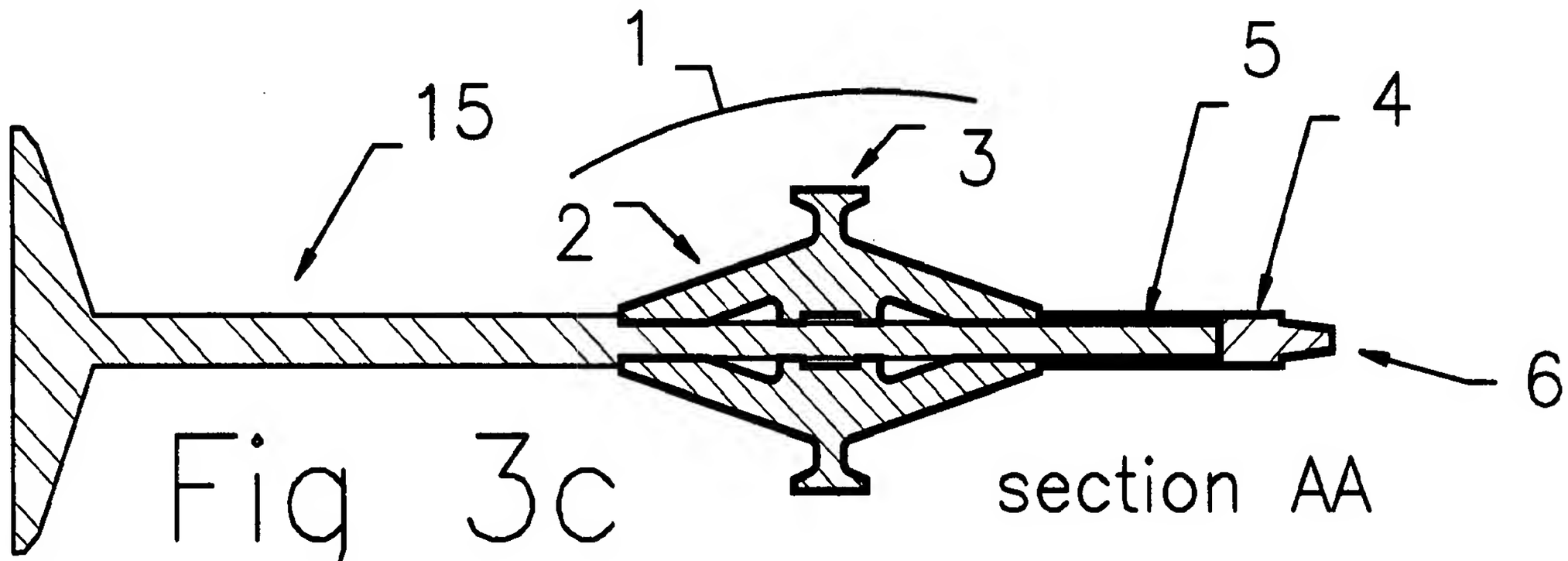


Fig 3c

section AA

Fig 3